NASA-CR-200201

IN TERIM

IN-51-CR

OCIT.

8378

p. 12

Grant No. NAG 2-438

Supplemental Status Report

February 1, 1995 - January 31, 1996

"Selection of Behavioral Tasks & Development of

Software for Evaluation of Rhesus Monkey

Behavior During Spaceflight"

Principal Investigator: Duane M. Rumbaugh
Co-Investigator: David A. Washburn
Co-Investigator: W. K. Richardson

Language Research Center

Georgia State University

University Plaza

Atlanta, GA 30303

Supplemental Status Report
February 1, 1995 - January 31, 1996

Behavior & Performance Project

I. SUMMARY OF FINDINGS: The results of several experiments were disseminated professionally during this semiannual period. These publications and presented papers represent investigations of the continuity in psychological processes between monkeys and humans. Thus, each serves to support the animal model of behavior and performance research. Of particular interest, at the Life Sciences and Space Medicine Conference and Exhibition we described the PTS and its three major spin-off applications to date. The audience was enthusiastic about the benefits of this technology investment by NASA for education of children with mental retardation and for research and enrichment of nonhuman primates. Questions and comments following the presentation were very positive--many suggesting even more potential applications of PTS (e.g., for intervention with stroke patients)--and we have agreed to present a follow-up paper at this year's meeting.

1. Rumbaugh, D. M., & Washburn, D. A. (1995). Attention and memory in relation to learning: A comparative adaptation perspective. In G. R. Lyon and N. A. Krasnegor (Eds.), Attention, memory, and executive function (pgs. 199-219). Baltimore: Brookes Publishing Company. (See Appendix)

Overview

In this chapter we offer a comparative perspective of attention and memory to the end that we better understand these basic processes in the development, learning, and competence of the human child. It is common knowledge that deficits in these processes interfere with social as well as academic success and are very difficult to correct. Remediation is characteristically limited, both in scope and in its generalization to real-world situations. Fortunately, comparative studies, particularly with chimpanzees (Pan) and rhesus monkeys (Macaca mulatta), have a great deal to tell us about attention, memory, and learning. Captive-born and -reared specimens are characteristically lacking in attention and prone to be both hyper emotional and hyper active. Thus, they might be viewed as natural preparations for research intended to ameliorate these conditions.

By good fortune, our primate research of recent years reveals several ways whereby chimpanzees have become highly attentive, task oriented, tenacious, and outstanding learners of language and video tasks who, also, have manifested substantial ability to generalize their skills to diverse test situations and contexts. Except for language skills, the same holds for rhesus macaques. Our comparative studies indicate (1) that deficits in attention, memory, and learning are not unique to humans, (2) that these

deficits can be profoundly attenuated, (3) that early environment is extremely important to the structuring of competence, (4) that computer technology can be of great assistance in rectifying these deficits, (5) that stable, interactive, communicative contexts within which the subject can exercise great control over what it does is important to the rectification of these deficits, and (6) that the competencies acquired by our primates both serve to instate solid attention, memory, and learning abilities and generalize with positive effect to conditions beyond those in which they were acquired.

2. Washburn, D. A., & Gulledge, J. P. (1995). Game-like Tasks: Leveling the Playing Field. Behavior Research Methods, Instruments, & Computers, 27, 235-238.

Abstract

Game-like computer tasks offer many benefits for psychological research. In this paper, the usefulness of such tasks to bridge population differences (e.g., age, intelligence, species) is discussed and illustrated. A task called ALVIN was used to assess humans' and monkeys' working memory for sequences of colors with or without tones. Humans repeated longer lists than did the monkeys, and only humans benefitted when the visual stimuli were accompanied by auditory cues. However, the monkeys did recall sequences at levels comparable to those reported elsewhere for children. Comparison of similarities and differences between the species is possible because the two groups were tested with exactly the same game-like paradigm.

3. Washburn, D. A., Sevcik, R. A., Rumbaugh, D. M., & Romski, M. A. (1995, April). The Psychomotor Test System for Research and Education. Paper presented at the Life Sciences and Space Medicine Conference and Exhibition '95, Houston, TX.

Abstract

In 1987, Georgia State University scientists, with the support of NASA and CNES, developed the Psychomotor Test System (PTS; also known by the name of its prototype, the Language Research Center's Computerized Test System or LRC-CTS). The PTS is a 386-based computer used to administer automatically a battery of software tasks. Computer-generated stimuli are presented on a color monitor, to which the subject must respond by manipulating a joystick in accordance with varied task demands. The battery of 18 tasks includes automated versions of many of the classic testing paradigms in cognitive psychology, human factors research, and comparative psychology. The PTS was designed for two purposes: (a) To support the psychological well-being of monkeys maintained for integrated physiological research both on the ground and Spacelab-based research; and (b) to study the effects of spaceflight on psychomotor function, learning, memory, attention,

perception, problem solving, and other psychological processes. Although the spaceflights for this research remain in the future, three distinct spin-offs or ground-based benefits have been realized already from the development of the PTS.

First, we have studied the utility of the test system for supporting the <u>psychological well-being</u> of rhesus monkeys maintained for space life sciences research. The necessity of promoting and monitoring the psychological well-being of research animals is not unique to spaceflight research; enrichment is mandated by federal law as well as by scientific and ethical considerations. As biomedical and behavioral laboratories struggle to comply with these requirements, it is increasingly clear that the PTS is unsurpassed as an enrichment device for addressing the multiple dimensions that constitute psychological well-being. The data from a series of experiments indicate that the device promotes health and the development of normal, adaptive behavior patterns when used with singly or group-housed animals. Thus, the PTS is uniquely useful for sustaining interest and activity, for providing challenge and control, and for assessing the psychological well-being of the research primate.

The PTS has also proven quite effective as an automated apparatus for research in <u>basic comparative cognition</u>--quite independent of spaceflight-related research questions. Many investigators have attempted to automate testing devices like the Wisconsin General Test Apparatus. Historically, the efforts have yielded frustration and failure. The discovery that the PTS can be used as an automated test apparatus defies this tradition. It has been successfully employed with old and new world monkeys, orangutans, chimpanzees, bonobos, and humans of varied ages. To date, investigators at over 30 laboratories around the world have requested and received this technology for their research. In the short time since its development, the PTS and related apparatus has been used in over 50 publications--covering a variety of research questions--in the peer-reviewed journal literature.

The PTS also benefits human children. Many domains of development and skill frequently have not been accessible for some <u>youths with mental retardation</u> and impaired oral language abilities. The PTS affords a battery of computer-facilitated nonverbal tasks that employ methodology that is appropriate for the communicative abilities of these children and young adults. We have utilized the PTS to examine performance in perceptual-motor, cognitive-learning, and neuropsychological function. For example, a recent study of the visual short-term memory skills of students with moderate mental retardation revealed that even lengthy retention intervals were tolerated with little difficulty. Data such as these underscore the advantage of studying heretofore untapped skills of persons with cognitive and linguistic disabilities.

We have also demonstrated that school-aged children with a range of cognitive disabilities can learn to use the joystick-driven system and proceed through an experimental assessment and learning battery as part of a classroom activity in school. Teacher and investigator observations indicate that there appear to be a range of gains from participating in this project, including increased social interaction (e.g., cooperation, competition) and development in the ability to attend to and execute tasks independently.

Clearly, the PTS is a NASA-supported technology that has already proven to be successful, even years before its spaceflight. The ambitious space life sciences research for which it was designed will be challenged to match the interesting and useful applications already characteristic of the PTS for earth-bound purposes. [Research supported by NASA NAG2-438 and NIH HD-06016.]

4. Filion, C., Washburn, D. A., & Fragaszy, D. M. (1995, June). Prediction of linear trajectories by rhesus macaques. Poster presented at the annual meeting of the American Psychological Society, New York, NY.

Abstract

Rhesus macaques were tested for their ability to predict, hence represent internally, the continuation of a moving but "interrupted" linear trajectory. Subjects were trained and tested for transfer on eight spatial orientations of a computerized task. For each trial, subjects were required to select one endpoint, out of five possible endpoints, that would be intersected by the trajectory if it were to continue. Subjects reached criterial training levels (of 80% average correct responses for 1,000 trials) on every orientation of the task. No significant differences were found for rate of acquisition across task orientations. All subjects performed below chance levels on the 35 novel probe trials (transfer tests). Error patterns on the probe trials were analyzed for their match to a representational, associative, or unidentified strategy. Results suggest that subjects learned a spatially-based associative strategy early in training that could be generalized with some tailoring across task orientations. Subjects tried to apply this strategy to the probe trials when possible.

5. Shields, W., Washburn, D. A., & Smith, D. A. (1995, June). Uncertainty in same-different judgments. Poster presented at the annual meeting of the American Psychological Society, New York, NY.

Abstract

Rhesus monkeys (Macaca mulatta) use an uncertain response adaptively to escape threshold trials in a psychophysical same-different task, even while operating simultaneously at many absolute stimulus levels and levels of difficulty. These

uncertainty behaviors defeat a variety of associative interpretations. They reveal the cognitive sophistication that animals bring to their behavioral regulation in uncertain situations, and underscore the similarity between humans' and animals' uncertain responses.

6. Washburn, D. A. (1995, April). A Comparative Investigation of Working Memory: Rehearsal in the Sketchpad? Paper presented at the meeting of the Southern Society for Philosophy and Psychology, Virginia Beach, VA.

Abstract

Investigations of working memory tend to focus on the retention of verbal information. The present experiments were designed to determine whether an active maintenance rehearsal process is used in the retention of visuospatial information. Rhesus monkeys (Macaca mulatta; $N = 6$) were tested as well as humans (total $N = 90$) because the nonhuman primates have excellent visual working memory but, unlike humans, cannot verbally recode the stimuli so as to employ verbal rehearsal mechanisms. A series of experiments was conducted using a distractor-task paradigm, a directed forgetting procedure, and a dual-task paradigm. No evidence was found for an active maintenance process for either species. Rather, it appears that information can be maintained in the visuospatial sketchpad without active rehearsal.

7. Washburn, D. A., & Putney, R. T. (1995, October). Pupillometric indices of dimensions of difficulty in visual-task performance. Poster presented at the 39th meeting of the Human Factors and Ergonomics Society, San Diego, CA.

Abstract

On the basis of previous experiments with rhesus monkeys and humans, a distinction has been made between *performance difficulty* and *procedural difficulty* in visual-task performance. Increasing the procedural difficulty of a task can actually improve accuracy and response time, whereas increasing performance difficulty reliably has the opposite effects. In the present experiment, undergraduate volunteers ($N = 22$) were required to recognize briefly presented, computer-generated forms in a divided visual-field task. An ISCAN RK-426PC was used to assess visual gaze and pupil dilation during testing. A Trial-Initiation Difficulty X Presentation Duration interaction was obtained, $F(1, 21) = 8.67$, $p < .05$. Subjects performed significantly better on the recognition task when it was difficult to initiate a trial than when it was easy (mean accuracy = 78% versus 71%). The effects of manipulating presentation duration were comparable in degree but opposite in direction, as responses were significantly more accurate in the easier condition (73% for 100 msec presentations versus 81% for 150 msec presentations). Presentation duration was not reliably

related to pupil dilation or position. In contrast, the pupils were significantly more dilated (by about 8%) in the difficult than the easy trial initiation condition. Fixation was also significantly more likely on the trials that were difficult to initiate. These divergent findings support the distinction between procedural and performance difficulty variables in visual task performance, and suggest two explanations for the effects. Manipulations of procedural difficulty may increase a subject's level of effort or arousal, which in turn benefits subsequent task performance. Additionally, difficult trial-initiation demands may be used to promote task-appropriate visual fixation, which may itself result in improved performance.

8. Washburn, D. A., Putney, R. T., & Henderson, B. (1995, October). Harder to do, easier to learn: Manipulations of attention in training. Poster presented at the 39th meeting of the Human Factors and Ergonomics Society, San Diego, CA.

Abstract

In previous studies, rhesus monkeys and humans were trained more rapidly on a variety of computerized tasks in which the experimental stimuli move than when the stimuli remain stationary. Subsequent investigations have revealed this effect to stem from the relative difficulty of catching moving versus stationary stimuli, rather than from the basic predisposition to attend to movement in the environment. However, the cost of such manipulations is that procedurally difficult training trials take longer to do, and thus fewer can be completed per unit of time. In the present study, we controlled the amount of time that was available for training under conditions in which sample stimuli either moved or remained stationary to determine whether the stimulus movement effects previously reported were an artifact of training time. Undergraduate student volunteers ($\underline{N}$ = 23) were required to learn the English equivalent for 16 arbitrary visuographic symbols in two 20-minute sessions using a symbolic matching task. Accuracy was significantly better on this task when the computer-generated stimuli were dynamic rather than static (85% versus 67%; $\underline{p} < .01$), and subjects manifest reliably higher levels of retention after 1 to 3 weeks for the symbol-word pairs that had been trained under moving-stimulus conditions (76% versus 59% for the stationary-trained pairs; $\underline{p} < .05$). In fact, the subjects were trained in one session on the verbal meanings of moving visuographic symbols to levels of accuracy that were significantly higher than were obtained after two sessions of stationary-stimulus training ($\underline{p} < .05$). Thus, manipulating procedural difficulty through stimulus movement appears to be a reliable, efficient, and almost cost-free means of promoting concentrated attention in training--particularly for tasks that are relatively simple or mundane.

II. Foot pedal task training

Sonny Carter Life Sciences Laboratory: We received at the Sonny Carter Life Sciences Laboratory (SCLSL) six young monkeys from the Ames Research Center (ARC). The animals had received some training on PTS, mostly through vivarium access in the social cages. However, each animal had been given PTS access during initial restraint training, and had mastered the cursor manipulation skills instated with the SIDE task.

At our laboratory, each monkey has now been trained in their vivarium cages on the SIDE, CHASE, PURSUIT, MTS, and DMTS tasks--the subset of PTS tasks that we will use in Bion 11 pre- and post-flight tests. A modified version of the training protocol developed for the Rhesus Project was used with these animals (as with the other monkeys being trained at ARC). It is important to note that criterial training of these monkeys required significantly fewer trials (and less time) than had been observed in the Rhesus Project. After initial SIDE training, the present monkeys reached the training criterion on the other four tasks in less than one week! For this reason, the new training protocol has been implemented for training in Moscow (see below).

One monkey (93-104) completed an extensive series of experiments in which he manipulated a joystick or foot-lever with the hand or foot. This animal has demonstrated the ability to manipulate the response device with either limb and without restraint on SIDE, CHASE, and PURSUIT tasks.

Four monkeys were also trained in Primate Produce Restraints (PPR) on the initial PTS version of the foot-pedal motor control task. (The foot-pedal motor control task is frequently abbreviated MC2; the initial PTS software for training these skills is called PEDAL.) This PTS task is designed systematically to transition an animal between a task like CHASE (i.e., move the cursor into contact with the target, a blue rectangle) and a simulation of the visual feedback available in the Russian MC2 task. S103 and S104 from our laboratory were also trained on the PEDAL task, but were not restrained. Each monkey was able to learn to press the joystick thrice with their foot, and then to hold the joystick at a midrange position for two seconds. We believe that such training will transfer to the use of a foot-pedal, and will facilitate training on the MC2 task for flight. The PEDAL software is currently being revised to accommodate information we obtained from our recent visit to Moscow, so that it might be even more effective in preparing monkeys for training on the MC2 task.

Ames Research Center: We have also worked with the Bionetics training staff to implement these procedures at ARC, and have analyzed the training data from the use of the PEDAL task. Six monkeys were tested in the PPRs on the PEDAL task. These animals had previously been trained to control a cursor in PTS tasks by skillful use of the joystick with a preferred hand. The animals were able to transfer these basic skills, albeit with less

precision, to the manipulation of a joystick by foot. No additional shaping was required.

Summary: Thus, it appears likely that the training for monkeys to use a foot-pedal on the MC2 task will be facilitated if (1) each monkey first learns to control a cursor by hand, (2) each monkey is then permitted to transfer these skills to foot-joystick use, and (3) a foot-pedal is finally introduced and the rich visual cues (e.g., moving cursor) are faded.

III. Locomotion training

Several monkeys were trained at our laboratory to walk on a treadmill, modified as described in the previous report. We have determined that it is reasonable to train young monkeys to walk quadrapedally or bipedally on the moving treadmill belt for 1 to 60 seconds, although we have been unable to signal the animal with respect to the number of limbs to use for locomotion in a particular session. We have developed a protocol for this training to be used at ARC and in Moscow.

IV. Training in Moscow

We are committed to providing a pool of flight animals that are trained on a specific subset of PTS tasks (for pre- and post-flight testing and enrichment). We are also determined to define and to monitor training procedures so that flight animals are highly practiced on the locomotion and postural tests. Additionally, we will support and facilitate the training of the foot-pedal motor control task. Finally, we must continue to provide environmental enrichment for, and monitor the psychological well-being of, all nonhuman primates that are maintained for this research. To achieve these ambitious goals, we have worked during this funding period to implement training procedures at the Institute for Bio-Medical Problems (IBMP) in Moscow, Russia.

John Gulledge, a graduate student and research technician at our laboratory, spent over four weeks in Moscow helping to establish the training procedures and resources. Project scientists also travelled to Moscow to meet with the Russians and to resolve training issues. The results of these negotiations were summarized an agreement, dated 4-August-95 (see Appendix).

In Moscow, we conducted a feasibility test to determine whether PTS training could be conducted by removing the young (and fully fed) monkeys from vivarium cages, chairing them in a PPR for 4 to 8 hours, giving them access to PTS, and then returning them to their home cages each evening. After one week of this experience, the monkeys had made no progress on the automated PTS training and were still exhibiting profound signs of distress (e.g., stereotypies, self-directed behavior). These results confirmed our prior findings that it is easier to train monkey in vivarium cages than in restraint, and that animals spend as much as the first 24

hours of restraint adapting to the new conditions. Even monkeys that have been trained on PTS tasks manifest significantly compromised productivity and performance in the first days of restraint. The striking results of the feasibility study in Moscow indicated clearly that PTS training could not proceed using short-term restraint.

As a consequence of this test, we were able to instate a vivarium-based training procedure for PTS. This type of training has several advantages, as it avoids the need to restraint-train a monkey while simultaneously trying to train it on PTS tasks. We further believe that ad libitum vivarium access to PTS is a good principle to follow for the duration of the Bion projects, as it provides support and evidence for each monkey's psychological well-being.

Data from the first week of training six monkeys using ad libitum vivarium access to PTS are now available. During this week, the animals performed an average of 284 SIDE trials per day. Task difficulty, titrated automatically contingent on performance, increased across blocks of trials indicating that the monkeys were able to respond to progressively more difficult trials during the week. At the same time, aborted trials (those that "drop-out" when the animal gives up and stops working) decreased across training. Two of the six monkeys were tested on the CHASE task and were able to complete some trials; however, both of the monkeys were moved back to SIDE for additional training.

Data for the remainder of training in Russia will be analyzed at our laboratory and summarized in the next semiannual report.

V. Analysis of the Adult Rhesus Restraint Test (ARRT)

A report was submitted on 30-August-95 that summarized the results of the ARRT test. There were numerous problems in the execution of this test. Time stampings for PTS data, physiological measures, and videotape records were not coincident, making difficult any relation of these databases. Videotape of control animals not of a quality that could be analyzed and, lacking these vivarium control data, little benefit was anticipated from the difficult task of coding ESOP videotapes taken at 1 frame/s. Injury to one animal resulted in an unbalanced experimental design. Finally, post-test physiological procedures (anesthesia, biopsies, etc.) had pronounced effects on performance and productivity that may have obscured more subtle influences by restraint itself. Notwithstanding, from the ARRT data we concluded that:

- Rhesus monkeys worked productively on the PTS, both in vivarium and ESOP environments.
- The monkeys were able to provide food for themselves via PTS performance (although the animals did, as we understand it,

lose some weight during the restraint period).

- The animals were apparently healthy physically and psychologically after the test--even after 18 days of continuous ESOP restraint. It is significant that the injury that resulted in one animal being removed from restraint was not incurred due to self-abuse, stereotypy, or PTS-directed behavior.

- Although a number of significant differences in PTS performance were found between vivarium and ESOP restraint conditions, each of these appear to be artifacts of a third variable, test phase.

- The quality and the quantity of PTS performance was reliably compromised in the post-test vivarium test. We interpret these alterations in performance and productivity as a result of one or more of the physiological procedures administered during this period.

- PTS performance generally improved across days within each test phase. This effect was pronounced for test phases that represented a change in environment (i.e., vivarium to ESOP, ESOP to vivarium).

- Trial production was not clearly cyclic in the vivarium condition, and was highly variable across test conditions. Possible error in the time-of-day stamping of the data precludes any strong interpretation of the patterns of activity across hours.

- Psychomotor performance was unaffected by restraint condition. Subjects appeared accurately and appropriately to manipulate the joystick for skillful control of the cursor. The data also suggest no difference between restraint conditions in the degree to which the subjects accurately predicted the movements of moving target stimuli.

- Pursuit tracking improved across days, particularly in the pre-test. This suggests either (a) that performance was not asymptotic when the test began, or (b) that the animals were relatively distractable in the early days of the first vivarium period.

- Performance on the DETECT task suggests that ESOP restraint did not impugn, but probability did not benefit, the monkey's ability to concentrate attention across sustained effort.

- Generally learning was not influenced by restraint condition. However, TI performance was compromised in the days following biopsies and other physiological procedures. This effect was particularly evident for transfer-of-learning under conditions

when information was greatly under-learned.

- Across conditions, the monkeys exhibited positive transfer as criterion levels increased. This is the hallmark of the type of learning afforded to organisms with complex brains and rich learning histories.

- Working memory was not differentially affected by restraint condition.

- The animals opted for a variety of tasks from the SELECT menus. Task preferences were not significantly different across restraint conditions.

- PTS performance was indicative of the health status of 84-316. As has been previously reported, PTS performance can provide useful indices of physical and psychological well-being.

- Videotape of the monkeys during the experiment revealed little. However, the animals appeared psychologically fit and generally engaged in adaptive behaviors. The 1 frame/s videotapes provide a useful resource for establishing coding schemes and for training observers pursuant to our Bion 11 study of psychological well-being.

- The critical task of analyzing relationship between PTS performance and physiological measures must be postponed until the time-markings in both pools of data are clearly correspondent.

VI. Research activities

Several experiments are ongoing at our laboratory. These efforts reflect feasibility studies for our Bion 11/12 science and/or follow-up experiments for previous findings. Current studies are designed to illuminate interactions between the dimensions of psychological well-being, to determine the effects on PTS performance of flight-relevant variables (e.g., light cycle, isolation/social facilitation, response limb and manipulandum), and to define similarities and differences between humans and monkeys in processes of perception, attention, memory, and other higher-order cognitive functions. Additionally, we continue to analyze a large corpus of training data that was produced in the Rhesus project. It is reasonable to anticipate that presentation and publication of these data will be summarized in future semiannual status reports.